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Soybean Varieties Respond to the Shade of Teak Trees

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ABSTRACT

Background: Light is one of the environmental factors that greatly affect the growth and yield of crops in general, including soybean plants. The purpose of this study was to determine the effect of shade on yield and yield components of soybean varieties

Methods: The research method was a randomized complete block design (RCBD) with three replications. The first factor was the kind of variety which consisted of two levels, i.e., Dena I and Anjasmara. The second factor was the level of shading, which consisted of four levels, i.e., 0, 10-20, 20-30, and 30-40%.

Result: The results showed that shade decreased the number of filled pods, dry pod weight per plant, 100 seeds weight, and seed yield ha⁻¹. As the shade increases, the lower the yield and component of soybean yields increases. The decrease in seed yield ha⁻¹ of Dena I variety at 10-20, 20-30, and 30-40% shade was 22, 14, and 50%, respectively, while the Anjasmara variety was 9, 49, and 59%. Shade decreases yields and yield components of Dena I and Anjasmara varieties. In the higher level of shade, the yield reduction will increase.

Keywords: Response, Shading, Soybean, Variety, Yield

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INTRODUCTION

32 ¹⁹ Solar radiation is one of the most important abiotic factors for agricultural production
33 (Liu *et al.* 2018). ⁵ A slight increase or decrease in light intensity for most plants will cause large
34 changes in the photosynthesis process (Wu *et al.* 2017). Light intensity affects important plant
35 processes such as physiology, biochemistry, and cell division (Wu *et al.* 2018). Many processes
36 in plants are disrupted by a decrease in ⁵ light intensity which brings about dramatic
37 developmental and physiological changes, leading to a rapid decline of these processes (Wu *et*
38 *al.* ⁵ 2016). Shades can affect the carbon balance of plants because the demand for carbohydrates
39 (sugar) ⁵ increases while production decreases: the rate of physiological processes increases while
40 the yield of photosynthesis decreases (Yang *et al.* 2018)). Thus, ¹⁰ tolerance to shade stress is
41 reduced at low photosynthetic rates in C₃ plants (Su *et al.* 2014). In addition, the carbohydrate
42 (sugar) pattern becomes an expensive process, as structural protein biosynthesis (especially
43 ⁵ chlorophyll protein) increases with increasing shade (Yang *et al.* 2018). The rate of
44 photosynthesis is the main driver of plant carbon balance, optimal and sustainable light
45 availability should also be considered to study the response of plants to shade stress.

46 ²⁶ The response of plants to a shaded environment is determined by their tolerance to
47 reduced light intensity. One of the effects of shade on plant morphology is that the plant stems
48 become taller because the plant stems are etiolated (Dhariwal *et al.* 1998). This morphological
49 condition causes the plants to fall easily so that they can reduce the yield of seeds. The shade of
50 50% during growth resulted in a decrease in soybean seed yields of between 37 and 74%
51 (Steppuhn *et al.* 2005), and in rice resulted in a decrease in the yield of more than 55%
52 (Sulistiyono *et al.* 2002). Another effect of shade on plant morphology is an increase in leaf area
53 (Kisman *et al.* 2007) which aims to make light absorption more efficient so that the
54 photosynthesis process can run normally (Djukri and Purwoko 2003). In the reproductive phase
55 of some soybean varieties, shade stress causes a faster flowering and harvesting age than in an
56 unshaded environment (Rahmanda *et al.* 2017).

57 By the research of Susanto and Sundari (2011), light reception by soybean plants is
58 different in each environment. The yield of soybean seeds under the shade of maize, cassava,
59 black paranet, and optimal environment were 0.35, 0.36, 1.33, and 2.13 tons ha⁻¹, respectively.
60 Sundari and Susanto (2015) reported ² that up to 75% shade intensity increased plant height and
61 specific leaf area, but reduced leaf number and ² area, light absorption rate, photosynthesis rate,

62 leaf chlorophyll index, number of filled pods, and seed weight per soybean plant. Each plant
63 genotype has a different tolerance to shade stress. Plants that are adaptive to low radiation have
64 increased leaf area ratios, stem leaf ratios, stem lengths, and decreased leaf thickness (Haque *et*
65 *al.* 2009).⁶ The purpose of this study was to determine the effect of shade on yield and yield
66 components of soybean varieties.

67 ⁴ MATERIALS AND METHODS

68 This research was carried out from November 2019 to February 2020 at Public Company
69 Perhutani Forest Management Unit Semarang at Grobogan, Central Java, Indonesia with
70 limestone Margalite soil with chemical composition: N total, P available, K available 0.15%
71 (low), 8.10 (medium), and 0.79 me 100 g⁻¹ (high), respectively.¹ A geographical position was
72 between 110° 15'-111° 25' east longitude and between 7° 1' - 7° 30' south latitude with a height of
73 79 m above sea level (ASL), and the average rainfall is 201 mm month⁻¹.

74 The experimental design used in this research was a¹ completely randomized block design
75 (RCBD) with four replications. The first factor was a variety,²³ which consisted of two levels, i.e.,
76 Dena I and Anjasmara. The second factor was shading which¹ consisted of four levels, i.e., 0; 10-
77 20; 20-30; and 30-40%.

78 ¹ Soil tillage was done by plowing, then manure was a dose of 2 tons ha⁻¹. The plots were
79 made in a size of 3.0 m x 3.0 m. The need for manure plot⁻¹ was 1.92 kg, Seeding was⁴ done by
80 sowing the soybean seeds on the prepared planting media. Soybean seedlings were planted at a
81 spacing of 40 cm x 15 cm. Phonska fertilizers¹ were given according to the treatment, namely the
82 first stage at 14 days and the second at 30 days after planting (DAP). Leaves fertilizer at a dosage
83 of 75 kg ha⁻¹ was given simultaneously at the age of 30 DAP in all plots. Irrigation cannot be
84 done and only rely on rainwater. Plant maintenance carried out included transplanting at the age
85 of 7 DAP and weed control at 14 DAP.

86 The parameters observed were the⁶ number of filled pods, the weight of dry pods, the
87 weight of 100 seeds, and the weight of seeds ha⁻¹.⁴ The data of observations were analyzed using
88 analysis of variance (ANOVA) at 5% significant levels. The treatment means were compared
89 using Duncan's new multiple range test (DMRT) at 5% significant levels.

90 RESULTS AND DISCUSSION

91 Analysis of variance (Table 1) showed that there was an interaction between varieties
92 and shade on the number of filled pods, dry pod weight, the weight of 100 seeds, and seed
93 weight ha⁻¹.

94 **Number of filled pods:** Based on the analysis of variance (Table 1) in the number of filled pods
95 there was an interaction between varieties and levels of shade. The highest number of filled pods
96 was Anjasmara variety without shade that did not differ with 10-20% shade, Dena I variety
97 without shade, or 10-20% shade. The minimum number of filled pods was Anjasmara variety
98 with 30-40% shade which was not different from Dena 1 variety at 30-40% shade (Table 2).

99 Shade levels of 10-20% in varieties Dena 1 and Anjasmara have not caused a decrease in
100 the number of filled pods, but starting at 20-30% shade levels, there is a decrease in the number
101 of filled pods. The increasing the shade, the decrease in the number of filled pods will increase.
102 The decrease in the number of filled pods of Dena I variety at 20-30 and 30-40% shade was 34.3
103 and 66.9%, respectively, while for Anjasmara variety was 61.8 and 74.8%.

104 The number of filled pods per plant in the shade-free environment in Dena 1 and
105 Anjasmara varieties was 59.0 and 61.5 pods, respectively, while in the shaded environment the
106 average was 35.58 pods and 30.17 pods (Table 2). The number of filled pods in plants in the
107 shaded environment is less, which is reduced by about 40-50 percent and this situation occurs
108 because the generative phase lacks light, which is the most sensitive phase to shade (Mathew *et*
109 *al.* 2000) so that the pods fall easily (Jiang and Egli 1993). Sundari and Susanto (2015) reported
110 that up to 75% shade intensity increased plant height and specific leaf area, but reduced leaf
111 number and area, light absorption rate, photosynthesis rate, leaf chlorophyll index, the number of
112 filled pods, and seed weight per soybean plant. With the presence of shade, stem diameter, total
113 biomass, leaf area, the number of internodes on the main stem, and the number of branches all
114 decreased (Wu *et al.* 2017).

115 The number of filled pods decreased with increasing shade stress (Table 2), which is
116 similar to the study (Da-yong *et al.* 2012). The number of filled pods decreased by about 50% at
117 50% shade stress and even decreased by about 75% at 75% shade stress. A decrease in the
118 number of filled pods can be caused by a lack of light for photosynthesis so that flowering and
119 pod-forming plants easily fall off (Jiang and Egli 1993). It seems that Dena 1 variety has
120 relatively little effect on pod number reduction compared to the Anjasmara variety.

121 One important effect of shade stress is a reduction in net photosynthesis (Liu *et al.* 2018).
122 Shade on soybean plants results in taller stems, expanded leaves, reduced number of pods,
123 reduced seed yields, and late ripening of pods (Susanto and Sundari 2011), other studies have
124 shown that lack of light results in the reduced number of pods formed (Kurosaki and Yumoto
125 2003). Plant growth can be increased by increasing the efficiency of light-harvesting in shade
126 conditions (Sundari and Susanto 2015) while Alridiwirah *et al.* (2018), states that total
127 chlorophyll, the highest was found on 50% shade intensity, the number of tillers, the highest was
128 found on no shade intensity. Chlorophyll a and b play a role in the photosynthesis process of
129 plants. Chlorophyll b functions as a photosynthetic antenna that collects light. The increase in
130 chlorophyll b content in shaded conditions is related to an increase in chlorophyll protein so that
131 it will increase the efficiency of the photosynthetic antenna function in Light-Harvesting
132 Complex II (LHC II). The low radiation adaptation of the plant is also characterized by an
133 enlarged antenna for photosystem II. Enlarging the antenna for photosystem II will increase the
134 efficiency of light-harvesting (Hidema *et al.* 1992). Chlorophyll b functions as an antenna that
135 collects light and then transfers it to the reaction center. The reaction center is composed of
136 chlorophyll a. Light energy will be converted into chemical energy at the reaction center which
137 can then be used for the reduction process in photosynthesis (Djukri and Purwoko, 2003).

138 **Weight of dry pods:** The weight of dry pods was influenced by the interaction between varieties
139 and shade levels (Table 1). The highest dry pod weight was achieved by Dena I variety without
140 shade, which was no different from the Anjasmara variety. The lowest dry pod weight for
141 Anjasmara variety with 30-40% shade but not different from Dena I variety at the same shade
142 level (Table 2). The weight reduction of dry pods in the shaded environment in Dena 1 and
143 Anjasmara varieties was 55 and 59%, respectively.

144 The reduction in weight of dry pods in both Dena I and Anjasmara varieties was started at
145 10-20% shade. At 20-30% shade levels, both Dena 1 and Anjasmara varieties reduced the weight
146 of dry pods by more than 50%.

147 The weight of dry pods in the shade-free environment for Dena 1 and Anjasmara varieties
148 was 19.16 and 17.51 g, respectively, while in the shaded environment the average was 8.69 and
149 7.19 g (Table 2). The reduction in weight of dry pods in shaded plants was due to the
150 photosynthesis process that did not run perfectly so that the net result of photosynthesis was not

151 optimal. This is ⁷ following the opinion of Khalid *et al.* (2019) that the presence of shade will
152 reduce the activity of chlorophyll and photosynthesis. ³ Light, temperature, humidity, etc. are
153 important factors that affect the growth process of plants. Light is not only a major participant in
154 plant photosynthesis, but also affects the relative content and quality of various macromolecules
155 in plants through the formation and transport of photosynthetic products (Goto, Yamamoto, and
156 Watanabe 1993), (Ohashi-Kaneko ³¹ *et al.* 2006).

157 Zhang *et al.* (2016) added that in the soybean plant, ¹³ short-term shading can reduce
158 photosynthesis, leaf temperature, stomatal conductance, transpiration, and water use efficiency
159 and increase intercellular CO₂ partial pressure, which leads to carbon gain and water loss.
160 ²⁸ Soybean is an important legume crop that shows sensitivity to shade, if it gets shade the stems
161 will elongate excessively, leading to falling apart and decreased yields (Lyu *et al.* 2021).
162 Meanwhile, Kuswantoro and Maghfiro (2005) stated that providing shade at various growth
163 stages ² had a significant effect on the number of flowers, ¹⁸ number of pods, number of filled pods
164 per plant, the weight of 100 seeds, and yield of dry soybean seeds.

165 ³⁰ In the relay strip corn-soybean intercropping system, the reduction in soybean
166 photosynthesis was due to the adjustment of the leaf structure to capture light, and the effect of
167 stomata characteristics on CO₂ absorption and translocation. Different shade-tolerant soybean
168 varieties have significant differences in responding to different degrees of shade. Shade-tolerant
169 varieties have advantages in the arrangement of leaf structure and stomata characteristics, which
170 are more conducive to the progress of photosynthesis. Therefore, shade-resistant varieties show
171 ²⁷ higher photosynthetic capacity and PSII activity, and biomass accumulation than shade sensitive
172 varieties under shade conditions (Fan *et al.* 2020)

173 ⁷ **Weight of 100 seeds:** The weight of 100 seeds was influenced by the interaction between the
174 varieties and the level of shade (Table 1). The highest weight of 100 seeds was Dena 1 variety
175 without shade and did not differ from 10-20% shade, Anjasmara variety without shade, 20-30,
176 and 30-40% shade (Table 2). The lowest seed weight of the Anjasmara variety was 10-20%
177 shade and did not differ from the Dena 1 variety with 20-30 and 30-40% shade.

178 ²⁹ The results of this study indicated that the ⁹ weight of 100 seeds was less affected by the
179 level of shade, but more dominantly influenced by the character of a variety. It is proven that the
180 Anjasmara variety in shaded conditions (30-40%) ⁹ soybean plants can still carry out the

181 photosynthesis process and produce seeds with seed sizes that match their genetic characters, but
182 in Dena 1 variety, 20-30% shade has experienced a weight loss of 100. seed. This is by the
183 opinion of Tang *et al.* (2010) stated that shade treatment caused a decrease in seed yield but had
184 no effect on seed size. The weight of 100 seeds represents the size of a seed. The weight of 100
185 seeds is influenced by genetic characteristics of each variety but also influenced by
186 environmental factors including light intensity. The seed size of each genotype or variety gave
187 different responses due to different light intensity treatments

188 Added by Ali *et al.* (2010) stated that soybean plants that grow in a shaded environment
189 will decrease photosynthetic activity, so that the allocation of photosynthate to the reproductive
190 organs is reduced, of course, this will result in a reduced number of pods, small seed size, and
191 reduced seed yield. The light intensity of 60 or 40% shade can cause a decrease in soybean seed
192 yields by up to 32% (Sundari and Susanto 2015). Kuswantoro and Maghfiro (2005) state that the
193 length of shading during the growth of soybeans is approximately 84 days, from the vegetative
194 phase to harvest, which will cause the allocation of photosynthate products not only for seed
195 formation but also for the formation and development of other morphology. persist in gripping
196 conditions.

197 **Weight of seed:** Based on the analysis of variance, there was an interaction between varieties
198 and shade levels on seed weight ha^{-1} (Table 1). The highest seed weight ha^{-1} was in the Dena 1
199 variety without shade and was not different from the Anjasmara variety without shade. The
200 lowest seed weight ha^{-1} of Anjasmara variety with 30-40% shade level, which was not different
201 from 20-30% shade, and Dena 1 variety with 30-40% shade (Table 2).

202 Seed weight ha^{-1} in the shadeless environment for Dena 1 and Anjasmara varieties were
203 1692 and 1575 g, respectively, while in the shaded environment the average was 1196 and 963 g
204 (Table 2). If it is broken down into different levels of shade, the decrease in yield ha^{-1} of Dena
205 variety is 10-20, 20-30, and 30-40%, respectively 22, 14, and 50%, while the Anjasmara variety
206 is 9, 49, and 59%.

207 The shade will reduce the seed weight ha^{-1} because the soybean crop lacks light. The
208 function of light is for the photosynthesis process. As the shade increases, the rate of
209 photosynthesis will decrease. Sundari and Susanto (2015) reported that up to 75% shade intensity
210 increased plant height and specific leaf area, but reduced leaf number and area, light absorption

211 rate, photosynthesis rate, leaf chlorophyll index, number of filled pods, and seed weight per
212 soybean plant. Each plant genotype has a different tolerance to shade stress. Plants that are
213 adaptive to low radiation experience an increase in leaf area ratio, stem leaf ratio, stem length,
214 and decrease in leaf thickness (Haque *et al.* 2009). Susanto and Sundari (2011)²¹ reported that the
215 growth and yield of soybean was influenced by the interaction of soybean genotypes with the
216 environment

217 The light environment¹⁰ is one of the most critical environmental factors affecting plant
218 growth and development (Gao *et al.* 2020).³ Shading not only causes changes in light intensity,
219 but also causes changes in environmental factors such as light quality, air humidity, CO₂
220 concentration, and soil temperature (Shi *et al.* 2015). Reduction of absorbed light results in a
221 reduction² in photosynthetic activity so that the allocation of photosynthate to the reproductive
222 organs is reduced. (Pekşen 2007) and as a result, seed yields decreased. Moula (2009) added to
223 rice plants that the shaded and unshaded rice yields were 0.76 and 2.21 tons ha⁻¹ respectively for
224 the Kazol Shail variety and BRRI.-32 1.83 and 3.63 tons ha⁻¹.

225 Regarding variety, Chen *et al.* (2019), said³ that varieties had a significant effect on yield
226 and each component factor, and light had a significant effect on spikelet filling, 1000 grain
227 weight, and yield. Shading caused a significant reduction in the weight of 1000 grains and
228 spikelet filling, which in turn led to a decrease in yield from 15.3 to 20.0%. The yield reduction
229 using shade black nylon net is higher than under shading white cotton yarn.

230 In intercropping soybeans with maize, the yields of soybean with one row of corn and
231 one row of soybeans, and³ two rows of soybeans planted in rows 40 cm wide were 54.69 and
232 16.83% lower than the single row of soybeans,³ respectively. These findings suggest that soybean
233 plants can regulate the morphological characteristics and anatomical structure of leaves under
234 different light environments (Yang *et al.* 2018)

235 ¹ CONCLUSION

236 The research results and the discussion above could be taken as follows. Shade decreased
237 the number of filled pods⁶, the weight of dry pods, the weight of 100 seeds, and the yield ha⁻¹ of
238 soybean varieties. The decrease in seed yield ha⁻¹ of Devon 1 variety at 10-20, 20-30, and 30-
239 40% shade was 22, 14, and 50%, respectively, while the Anjasmara variety was 9, 49, and 59%.

240

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243

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366 **Table 1.** Analysis of variance all parameters

	4 Number of filled pods	Weight of dry pods	Weight of 100 seeds	Weight of seed ha ⁻¹
Variety	0.76 ns	5.86 *	0.05 ns	9.00 **
Shading	23.43 **	89.11**	2.03 ns	31.33 **
Variety × shading	10.86 **	40.29 **	6.32	40.19 **
			**	
CV (%)	27.82	16.89	4.56	10.29

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369 **Table 2.** Interactions of varieties and shading to the 12
370 pods, weight of 100 seeds, and weight of seeds ha⁻¹

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Variety	Shading	Observation			
		7 Number of filled pods	Weight of dry pods (g)	Weight of 100 seeds (g)	Weight of seed ha ⁻¹ (g)
Dena 1	0	59.00 a	19.16 a	16.19 a	1692.00 a
	10-20	48.50 ab	11.40 b	16.06 a	1312.50 c
	20-30	38.75 bc	9.36 b	14.18 c	1446.50 bc
	30-40	19.50 d	5.30 cd	14.83 bc	830.75 d
Anjasmara	0	61.50 a	17.51 a	15.87 ab	1575.25 ab
	10-20	51.50 ab	11.78 b	14.04 c	1437.50 bc
	20-30	23.50 cd	6.55 c	15.60 ab	802.75 d
	30-40	15.50 d	3.23 d	16.08 a	651.00 d

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